

Global Aerosols 5-day Forecasts:

BACKGROUND

The NEMS coupled app (GFS-CHEM) includes two components: The NCEP Global Forecast System ([GFS V15](#)) and GSDCHEM. GSDCHEM is a National Unified Operational Prediction Capability (NUOPC) based chemistry component developed to replace the current NEMS GFS Aerosol Component (NGAC at 1x1°, Wang, et al. 2018) GSDCHEM includes the WRF-Chem (Grell, et al. 2005) chem_driver with updates for consistency with the NASA Goddard Operational Chemistry and Aerosol Radiation and Transport (GOCART; Chin, et al., 2007) version. The chemistry and aerosol modules used for GFS-CHEM include simple sulfur chemistry, hydrophobic and hydrophilic black and organic carbon, and a 5-bin sea salt module. Additionally, included is the FENGSHA (Dong, et al. 2016) 5-bin dust module, wildfires modeling using Fire Radiative Power (FRP) and smoke emissions from the NESDIS Global Biomass Burning Emissions Product (GBBEPx; Zhang, et al., 2014; Zhang, et al., 2012). Plume rise modeling is done with a 1-d cloud model (Grell & Freitas, 2014), and, optionally, volcanic ash emissions are also included. The global anthropogenic emission is from the Community Emissions Data System (CEDS) based on 2014 inventory. Tracers are transported by the dynamics as well as the GFS physics (GFS PBL and Simple Arakawa Shubert (SAS) deep and shallow convection parameterization). Subgrid scale wet scavenging and transport is done inside the two SAS routines.


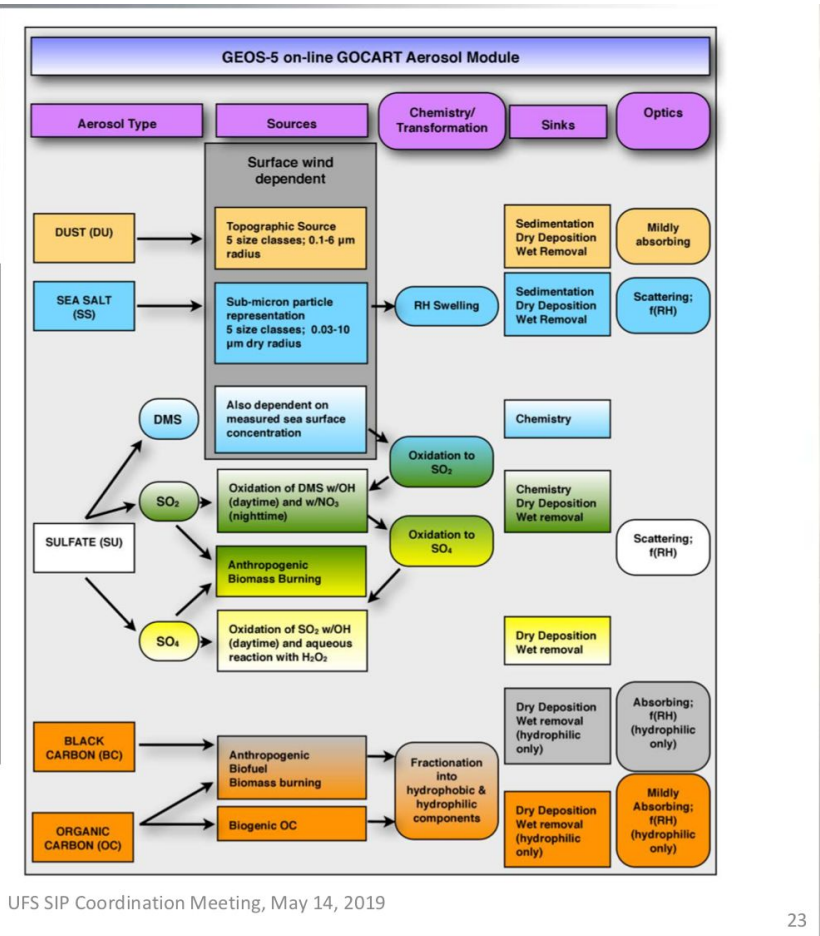
The system runs at FV3 cube sphere C384L64 resolution (~25 km) in the NCEP Global Ensemble Forecast System (GEFS) production suite, but with GOCART simple aerosol chemistry (20 species) run to 120 forecast hours four times per day. GFS-Chem currently requires 40 nodes to run 5 days in 37 cpu minutes on the Dell Phase III systems.

GOCART Module

In-line chemistry advantage

- **Consistency:** no spatial-temporal interpolation, same physics parameterization
- **Efficiency:** lower overall CPU costs and easier data management
- **Interaction:** Allows for feedback to meteorology

GOCART diagram provided by Peter Colarco (GSFC)

Technically, coupling occurs two-way, as mixing ratios of chemical tracers are exchanged between FV3GFS and GSDCHEM at each coupling step to be advected by FV3 dynamical core. However, at this point coupling is considered to be only one way in this milestone from a scientific standpoint, since feedback to the meteorology is not yet activated.

At each coupling time step, a complete set of fields is provided by FV3GFS to GSDCHEM, which includes them in chemistry computations and returns updated mixing ratios for the chemical tracers to FV3GFS. Tracer concentrations and some diagnostic chemical output are included in FV3GFS history files.

All 2D and 3D fields exported by FV3GFS are initialized using baseline input data provided for regression testing. FV3 data structures (IPD_Data) corresponding to these fields are shown in Table 1. 19 chemical tracers are defined in the FV3GFS input field_table file with a spatially constant non-zero value at the surface. These tracers are also added to the diag_table file to be included in FV3GFS dynamics history files.

More information is available from the following links:

- [Partha Bhattacharjee, NCEP/EMC AMS 2020 presentation](#)
- [Rick Saylor's, NOAA/ARL, ICAP 2019 presentation](#)
- [GEFS-Aerosols development history](#)
- [GFS-Aerosols Real-time Forecasts](#)
- [GFS-Aerosol evaluation web graphics](#)

Global Aerosol modeling communities Users:

- [ICAP](#) : International Centers for Aerosol Prediction (ICAP)
- [WMO SDS-WAS](#) (WMO Sand and Dust Storm-Warning and Advisory System)
- [Global Air Quality Index project](#) (Singapore Met offic)
- [WMO VFSP-WASL](#) (WMO Vegetation Fires and Smoke Pollution Warning System)

EVALUATION

GEFS-Aerosols retrospectives are run from March 2019 and ending March 2020. Evaluations against the ATOM-1 2016 field experiment have already been performed by NOAA/OAR. Evaluation followed previous NGAC protocols (Bhattacharjee, et al. 2018) and [are available here](#). The following fields are evaluated daily by comparing model outputs to

- MODIS satellite AOD 1° gridded product
- VIIRS satellite AOD 0.25° degree gridded product
- AERONET AOD especially stations near dust and smoke sources
- International Centers for Aerosol Prediction (ICAP) ensemble forecast - 1° total and dust AOD
- NASA GEOS-5/MERRA-II gridded total AOD and speciated analyses (SO₄, dust, OC, BC)
- Global PM_{2.5} and PM₁₀ surface measurements
- Monthly compared Calipso aerosol profiles

The evaluation web site included daily and monthly averaged comparisons to above observations/analyses of

- Gridded AOD RMSE, Bias and correlation on global and regional maps
- diurnal and daily time series at AERONET sites

GEFS-Aerosols Output

Outputs will be in grib2 and include the same fields currently output by NGAC but at a finer 0.25 degree resolution. These fields will include:

Table 1. Aerosol name	unit	Domain
3D fields		
DUST1_ON_HYBRID_LVL	ug/m3	1 hybrid level
DUST2_ON_HYBRID_LVL	ug/m3	1 hybrid level
DUST3_ON_HYBRID_LVL	ug/m3	1 hybrid level
DUST4_ON_HYBRID_LVL	ug/m3	1 hybrid level
DUST5_ON_HYBRID_LVL	ug/m3	1 hybrid level
SEASALT2_ON_HYBRID_LVL	ug/m3	1 hybrid level
SEASALT3_ON_HYBRID_LVL	ug/m3	1 hybrid level
SEASALT4_ON_HYBRID_LVL	ug/m3	1 hybrid level
SEASALT5_ON_HYBRID_LVL	ug/m3	1 hybrid level
BCPHILIC_ON_HYBRID_LVL	ug/m3	1 hybrid level
BCPHOBIC_ON_HYBRID_LVL	ug/m3	1 hybrid level
OCPHILIC_ON_HYBRID_LVL	ug/m3	1 hybrid level
OCPHOBIC_ON_HYBRID_LVL	ug/m3	1 hybrid level
SO4_ON_HYBRID_LVL	ug/m3	1 hybrid level
2D fields		
AER_OPT_DEP_at550 (total)		entire atmosphere
DUST_AER_OPT_DEP_at550		entire atmosphere
SEASALT_AER_OPT_DEP_at550		entire atmosphere
SULFATE_AER_OPT_DEP_at550		entire atmosphere
ORGANIC_CARBON_AER_OPT_DEP_at550		entire atmosphere
BLACK_CARBON_AER_OPT_DEP_at550		entire atmosphere
DUST25_SFC_MASS_CON (dust pm2.5)	ug/m3	1 hybrid level
SEAS25_SFC_MASS_CON (sea salt pm2.5)	ug/m3	1 hybrid level
PM10_SFC_MASS_CON	ug/m3	1 hybrid level
PM25_SFC_MASS_CON	ug/m3	1 hybrid level
PM10_COL_MASS_DEN	kg/m2	entire atmosphere
PM25_COL_MASS_DEN	kg/m2	entire atmosphere
DUST_COL_MASS_DEN (PM2.5)	kg/m2	entire atmosphere
SEAS_COL_MASS_DEN (PM10)	kg/m2	entire atmosphere
BC_COL_MASS_DEN	kg/m2	entire atmosphere
OC_COL_MASS_DEN	kg/m2	entire atmosphere
SULF_COL_MASS_DEN	kg/m2	entire atmosphere

References

- Bhattacharjee, P. S., Wang, J., Lu, C.-H., and Tallapragada, V (2018). The implementation of NEMS GFS Aerosol Component (NGAC) Version 2.0 for global multispecies forecasting at NOAA/NCEP
– Part 2: Evaluation of aerosol optical thickness. *Geosci. Model Dev.* 11, 2333–2351, <https://doi.org/10.5194/gmd-11-2333-2018>.
- Chin, M., Diehl, T., Ginoux, P., and Malm, W. (2007). Intercontinental transport of pollution and dust aerosols: implications for regional air quality, *Atmos. Chem. Phys.*, 7, 5501–5517, <https://doi.org/10.5194/acp-7-5501-2007>
- Dong, X., Fu, J. S., Huang, K., Tong, D., and Zhuang, G., (2016). Model development of dust emission and heterogeneous chemistry within the Community Multiscale Air Quality modeling system and its application over East Asia, *Atmos. Chem. Phys.*, 16, 8157–8180, <https://doi.org/10.5194/acp-16-8157-2016>.
- Grell, G.A. ,S.E. Peckham, R. Schmitz and S.A McKeen, G. Frost, W. Skamrock, B. Eder (2005). Fully coupled online chemistry within the WRF model: description and applications. *Atmos. Envir.* 39, 6957-6975. <https://doi.org/10.1016/j.atmosenv.2005.04.027>
- Grell, G. A., & Freitas, S. R. (2014). A scale and aerosol aware stochastic convective parameterization for weather and air quality modeling. *Atmospheric Chemistry and Physics*, 14,5233– 5250. <https://doi.org/10.5194/acp-14-5233-2014>
- Hoesly, R. M., Smith, S. J., Feng, L., Klimont, Z., Janssens-Maenhout, G., Pitkanen, T., Seibert, J. J., Vu, L., Andres, R. J., Bolt, R. M., Bond, T. C., Dawidowski, L., Kholod, N., Kurokawa, J.-I., Li, M., Liu, L., Lu, Z., Moura, M. C. P., O'Rourke, P. R., and Zhang, Q.: Historical (1750–2014) anthropogenic emissions of reactive gases and aerosols from the Community Emissions Data System (CEDS), *Geosci. Model Dev.*, 11, 369-408, <https://doi.org/10.5194/gmd-11-369-2018>, 2018.
- Wang, J., Bhattacharjee, P. S., Tallapragada, V., Lu, C.-H., Kondragunta, S., da Silva, A., Zhang, X., Chen, S.-P., Wei, S.-W., Darmenov, A. S., McQueen, J., Lee, P., Koner, P., and Harris, A. (2018). The implementation of NEMS GFS Aerosol Component (NGAC) Version 2.0 for global multispecies forecasting at NOAA/NCEP – Part 1: Model descriptions, *Geosci. Model Dev.*, 11, 2315–2332, <https://doi.org/10.5194/gmd-11-2315-2018>.
- Zhang, X., Kondragunta, S., Ram, J., Schmidt, C., and Huang, H.C. (2012). Near-real-time global biomass burning emissions product from geostationary satellite constellation, *Journal of Geophysical Research*, 117, D14201, doi:10.1029/2012JD017459.
- Zhang, X., Kondragunta, S., da Silva, A., Lu, S., Ding, H., Li, F., and Zhu, Y.: The blended global biomass burning emissions product from MODIS and geostationary satellites (GBBEPx),

http://www.ospo.noaa.gov/Products/land/gbbepx/docs/GBBEPx_ATBD.pdf (last access: 1 June 2018), 2014.